DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA 91125

WHY WAS IT EUROPEANS WHO CONQUERED THE WORLD?

Philip T. Hoffman

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Abstract

By the eighteenth century, Europeans dominated the military technology of gunpowder weapons, which had enormous advantages for fighting war at a distance and conquering other parts of the world. Their dominance, however, was surprising, because the technology had originated in China and been used with expertise in Asia and the Middle East. To account for their prowess with gunpowder weapons, historians have often invoked competition, but it cannot explain why they pushed this technology further than anyone else. The answer lies in the peculiar form that military competition took in western Europe: it was a winner take all tournament, and a simple model of the tournament shows why it led European rulers to spend heavily on improving the gunpowder technology, and why political incentives and military conditions kept such a tournament from developing elsewhere in the world. As a result, rulers elsewhere in Eurasia had much less reason to advance the gunpowder technology or to catch up with the Europeans. The consequences were huge, from colonialism to the slave trade and even the Industrial Revolution.

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1 Introduction

In recent years, historians, economists, and other social scientists have energetically debated when Western Europe first forged ahead of other parts of the world–in particular, advanced parts of Asia–in the race toward economic development. Was it only after 1800, with the Industrial Revolution well underway, that Western European per-capita incomes, labor productivity, or technology diverged? Or was it earlier, before the Industrial Revolution?[1]

In this debate, one area in which Western Europe possessed an undeniable comparative advantage well before 1800 seems to have been overlooked–namely, violence, or at least violence with gunpowder weapons.[2] The states of Western Europe were simply better at making and using artillery, firearms, fortifications, and armed ships than other advanced parts of the world and they had this advantage long before 1800. They used this gunpowder technology to wage war at home and to establish outposts abroad. The result was that by 1800 Europeans had conquered some 35 percent of the globe and were preying upon lucrative trade routes as far away as Asia. They took control of even more territory in the nineteenth century.[3] Some of the land they subjugated had come into their hands because of new diseases that they introduced into vulnerable populations, and in these instances–in the Americas in particular–their advantage was not just military, but biological as well.[4] But other inhabitants of densely populated parts of

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[1] For the divergence debate, see Wong 1997; Pomeranz 2000; van Zanden 2003; Goldstone forthcoming, Allen 2005; Broadberry and Gupta 2005. For arguments in favor of institutions, see North and Thomas 1973; North and Weingast 1989; Acemoglu, Johnson et al. 2002. For the other explanations, see Cosandey 1997; Jacob 1997; Mokyr 2002; Clark 2003; Clark 2007.

[2] If we measure violence simply by the number of people conquered, then the early modern Europeans would no doubt be surpassed by the Mongols and others. But it was the Europeans' proficiency with the gunpowder technology that made them stand out.

[3] Headrick 1981; Parker 1996, 5.

[4] Crosby 1967; Diamond 1997; and Crosby 2004, emphasize disease, but Brooks 1993, suggests that its role may well have been exaggerated. Military technology was in any case important too, notably the horses and the small galleys that Cortes constructed for the conquest of Tenochtitlan Gardiner 1956. Familiarity with this technology was widespread in Europe, even among people (such as the majority of the conquistadores) who were not professional men of arms. There was of course more to the story of European conquest than disease and military technology. Luck and rivalries among people and powers outside Europe also had an enormous role to play Black 1998, and rulers in Asia might have had more reason to restrict maritime trade, which would in turn discourage the

Eurasia would have had the same biological edge. Why was it therefore the Western Europeans who took over the Americas, and not the Chinese, the Japanese, or the Indians?

Patterns of trade support the claim that Europeans had a comparative advantage in the gunpowder technology, for from the sixteenth century on they were exporting handguns and artillery to the rest of the world, and European experts were being hired through Asia and the Middle East to help with gun making and with the tactics of fighting with gunpowder weapons. In seventeenth-century China, even Jesuit missionaries were pressed into service to help the Chinese Emperor make better cannons.[5]

It is nonetheless surprising that western Europe had come to dominate this technology of gunpowder weapons so early. Firearms and gunpowder, after all, had originated in China and spread throughout Eurasia, and for at least a while, states outside western Europe did become proficient at manufacturing or exploiting the new military technology. The Ottomans, for instance, made high quality artillery in the early sixteenth century.[6] And the Japanese discovered—some twenty years earlier than Western Europeans—the key tactical innovation (volley fire) that allowed infantry soldiers with slow loading muskets to maintain a nearly continuous round of fire.[7] Yet by the late seventeenth century, if not before, Chinese, Japanese, and Ottoman military technology and tactics all lagged behind what one found in western Europe.[8]

Why did these other powerful states fall behind? This question has attracted a number of gifted military historians, but most simply substantiate the Europeans' proficiency, without unearthing its underlying causes. The closest they come to a deeper explanation is the claim that military competition in Europe gave the Europeans an edge. The argument has been formulated most cogently by Paul Kennedy, who points to Europe's competitive markets and persistent military rivalries. In his view, while military rivalry created an arms race, competitive markets fostered military innovation and kept one country from establishing an empire.[9]

The military sector in early modern Europe (in other words, Europe before 1800) did experience rapid and sustained productivity growth; prolonged innovation of that sort was unknown in the rest of the economy.[10] But Kennedy's competition is not the final answer, for it

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development of naval technology and of the sort of private trading companies that spearheaded European expansion Lee and Temin 2004.

[5] See Parry 1970; Inalcik 1975; Parker 1996, 129-136; Black 1998, 30-32, 83-84; Heywood 2002; Agoston 2005, 10-12, 193-194, and Hoffman 2010, who shows that in the seventeenth and eighteenth centuries, the relative price of handguns was lower in Europe than in Asia. The Jesuits: Josson and Willaert 1938, 361-364, 580; Needham 1954, 5, part 7: 392-398; Spence 1969, 6-9, 14-15, 26; Waley-Cohen 1993,

[6] Guilmartin 1974, 255-263; Agoston 2005,

[7] With volley fire, infantrymen were trained to line up in long rows. The first row would fire their muskets, and while they were reloading, the rows behind them would advance to the front and take their place on the firing line. For volley fire in Europe and Japan, see Parker 1996, 18-19, 140-141.

[8] Agoston, 10-12, 193-94, argues that the European technological superiority was minimal, at least until the late seventeenth century, but he does admit that it was "European military experts who sold their expertise to the Ottomans and not vice versa."

[9] Kennedy 1987, 16-24

[10] Hoffman 2010, and Carlo Cipolla's pioneering study Cipolla 1965.

leaves far too much unexplained. To begin with, competitive markets do not always stimulate innovation. The clearest example comes from agriculture in early modern Europe, which had highly competitive markets but witnessed virtually no productivity growth.[11] What kept early modern European farmers from reaping the productivity gains of soldiers and sailors? What, in short, other than competition alone, was different in the military sector?

Nor do ongoing military rivalries always promote innovation. They in fact failed to do so in eighteenth-century India and southeast Asia. The case of India, as we shall see, is particularly illuminating, for like Europe it had markets and incessant warfare, and the combatants were quick to adopt the latest weapons and tactics. The innovations, however, by and large originated in the West.

The answer lies with the peculiar form of competition that European rulers were engaged in. It was a winner take all tournament that spurred rulers to improve military technology in the broadest sense of the word, even at the expense of the rest of the economy. In early modern Europe, political and military conditions were conducive to advances in the gunpowder technology. Elsewhere, however, they were not, and that is why Europeans pushed the gunpowder technology further than anyone else and why the rest of the world had trouble catching up.

Understanding why requires a look at the political, military, and fiscal incentives rulers faced, both in Europe and in other parts of Eurasia. It also requires an analysis of the costs and benefits of other military technologies besides gunpowder. We will start with Europe before 1800 and use it to motivate a simple tournament model, which will then be applied to the rest of the world and to Europe after 1800. The result will be a deeper understanding of why Europeans came to dominate the gunpowder technology, which in turn made world conquest possible. The consequences were huge—from colonialism to the slave trade and even the Industrial Revolution.[12]

2 The Tournament in Europe Before 1800

The states that coalesced in Europe in the waning days of the Middle Ages by and large had a single purpose, at least if we judge by what they levied taxes and borrowed money for. That purpose was clearly warfare. True, funds were spent on justice and palaces, and there was a pittance for transportation and famine relief. But particularly in the major powers, some 40 to 80 percent of the budget went directly to the military, to defray the costs of armies and navies that fought almost without interruption (Table 1). The fraction of the budget devoted to war climbed even higher—to 95 percent in France during the 30 Years War—if we add sums spent subsidizing allies or paying of the debts of past wars.[13]

[11] Hoffman 1996; Clark 2007. Whether competitive markets do stimulate innovation will depend on property rights and other factors.

[12] For arguments that the Industrial Revolution was at least in part caused by Britain's naval spending and the by the share of international trade that its military victories won, see O'Brien 2006; Allen 2009.

[13] For money spent on the military, see Hoffman and Rosenthal 1997, Table III.1.

In early modern Europe, decisions about war typically lay in the hands of a ruler such as a king or a prince. He would of course be advised by councilors and influenced by elites, and an influential minister might sometimes be dictating most of the decisions. But the assumption that a king or prince made the decisions about war is not far from historical reality. Even in eighteenth-century Britain, where Parliament and the cabinet decided whether to commence hostilities, the choices about the conduct of the war once it had begun were ultimately up to the king.[14]

What then made European kings take up arms? That question has to be answered if we are to understand what the tournament was. In Europe's major powers, the rulers often won control of warfare in the process of assembling their states in the late Middle Ages or the sixteenth century. They might have constructed their states by defeating domestic and foreign rivals, but typically they offered even conquered provinces protection from foreign enemies, in return for tax revenue. In modern terms, they provided the public good of defense in return for taxes.

That public good was precious, as anyone who suffered through the horrors of the 100 Years War in France or the 30 Years War in central Europe could testify. But the rulers of early modern Europe likely provided far more defense than their average subject would have wanted. They went on the offensive too, and not just to protect their kingdoms.

The reasons were not hard to understand. The kings and princes had been raised to fight one another, with toy soldiers, pikes, and firearms as children and actual training in their youth. Advisers like Machiavelli might tell them that princes "ought to have no object, thought, or profession but war." Their own fathers would teach them that war was a path to glory, a means to "distinguish [kings] . . . and to fulfill the great expectations ...inspired in the public," in the words of Louis XIV's instructions for his son. For them, fighting had gone beyond the needs of defense and become, in the words of Galileo, a "royal sport."[15]

Glory did recede as a motive for war in the eighteenth century, when the major powers might fight simply to preserve their reputation, to gain commercial advantage, or to snatch territory from weaker neighbors. But war was still "what . . . rulers did," the normal target for their ambitions. It continued to appeal to them, just as it long had attracted much of the European aristocracy.[16]

For the major monarchs of early modern Europe, victory was thus a source of glory or a way to enhance their reputation. Grabbing territory from small neighbors would add to their standing and augment their resources. And although they might lose small amounts territory themselves, they faced no major downside risk to their thrones, at least in the larger states, for loss in battle in

[14] Harding 1991, 28-30; Lynn 2000. Rodger makes it clear that the cabinet had enormous influence over the way Britain fought wars in the eighteenth century, and Parliament often interfered in foreign affairs. Nonetheless, "foreign policy was still the king's prerogative" (Rodger 2004, 242). For Renaissance Italy, see Mallett 1974, 88. In Elizabethan England (Pettegree 1988,), foreign policy could be shaped by courtiers, soldiers, and merchants, but their interests often coincided with those of the queen and her councilors, who made the ultimate decisions.

[15] Louis-XIV and Sonnino 1970, 124; Machiavelli 1977, 247; Hale 1985, 29-32.

[16] Lynn 2000; Bell 2007, 29-35 (the source of the quotation).

anything but a civil war never toppled a major monarch from his throne, at least in the years 1500-1790 (Table 2).

Europe's major monarchs thus had every reason to fight and even stronger reasons to outdo their neighbors and win victories. Of course not all rulers would participate. Some countries would be too small, and others (the Netherlands in the eighteenth century, for example), though big enough to fight, would bow out, or at least not enter a particular war.[17]

This sort of contest is a winner take all tournament, and a simple model of such a tournament does more to explain why Europe advanced ahead of everyone else in using the gunpowder technology than the military historians' arguments about competition. The prize in the European tournament will turn out to have been valuable enough (relative to the costs involved) get European rulers to expend huge amounts of effort. The effort in turn went not just to pay for larger armies and navies but also to improve tactics, logistics, and military technology.

The clearest mark of all this effort was the huge great increase in the tax revenues that central governments collected, at least among the major powers. For France and England, where fiscal records begin early, the per capita tax burden (measured in grams of silver) rose over 6-fold between the 1540s and the 1780s (Table 3). Picking other decades or measuring per-capita taxes in grain or days of a workman's labor would not change the results appreciably. By the eighteenth century, France may have been spending 5 to 10 percent of its GDP on military, and Great Britain even more—perhaps as much as 28 percent.[18] For countries that were still poor by modern standards, these figures are quite high. For comparison, at the end of the Cold War, the United States was devoting 5 percent of its GDP to the military, and the USSR perhaps 10 percent.[19]

Rulers also strived to improve military technology, in the broad sense of the term: not just the design and manufacture of ships and weapons, but tactics, logistics, and training too. In the sixteenth century, King Philip II of Spain recruited talented military architects from Italy and skilled gunners from Flanders, France, and Germany. He also rewarded military inventors and established academies to train military engineers. Two centuries later, the French were subsidizing the British iron master William Wilkinson in an effort to acquire British technology for manufacturing cannons.[20]

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[17] The cost of wars in the late seventeenth and early eighteenth century and the political difficulties of changing the Dutch fiscal system forced the Netherlands to remain neutral for much of the eighteenth century. The Dutch did not stop fighting altogether, but they ceased being an innovator in land and naval military technology: indeed, by the 1720s the Dutch navy was hiring British shipwrights. See Levy 1983, 37-38; Glete 1993, 411; de Vries and van der Woude 1997, 117, 122-123

[18] For Great Britain, the estimates come from Kennedy 1987, Table 2. They reach 27 percent during the Seven Years War and 28 percent during the wars of the French Revolution and Napoleon. For France, I assume that taxes are 12 percent of GDP and allow military expenditure to range from 45 to 85 percent of tax revenues. The 12 percent figure is derived from Mathias and O'Brien 1976, Table 5.

[19] Brzoska 1995, Table 3.

[20] Traité pour l'établissement de deux hauts fourneaux pres Montcenis 1782; Cipolla 1965; Goodman 1988, 123-141; Chaloner, Farnie et al. 1989, 19-32.

All this effort improved the gunpowder technology. It also helped spread the best of the technology, through espionage, efforts to copy what was successful, and Europe's longstanding market for weapons and military skills. Better technology was not adopted overnight—otherwise no ruler would have had an incentive to innovate—but it eventually diffused among the military powers and kept any one of them from gaining a monopoly on military strength. The effect was to make the European tournament work almost like an idealized prize system that put winning ideas into the public domain.

3 A Model of the Tournament

A simple model of the sort of tournament the rulers of early modern Europe were engaged in can help explain why they advanced the gunpowder technology and why rulers elsewhere in Eurasia lagged behind. We will sketch the model first, and then show that it fits the evidence both in early modern Europe and in other parts of the world.

The model we will use is taken from Fullerton and McAfee's analysis of a research tournament in which heterogeneous contestants exert effort to win a prize P.[21] The contestants devote their effort to finding an innovation, with the prize going to the one with the best innovation. Fullerton and McAfee had in mind competitors undertaking research to find innovations, but for our purposes, the contestants will be rulers who are seeking to improve a military technology, and in particular the gunpowder technology. They may do so by conducting research, but they can also advance the technology via learning by doing when they fight wars. Although we will not model the choice between research and fighting, the expected gains from getting the best innovation can be interpreted as the expected gains from winning a war, making the incentives to win the prize no different from the incentives to defeat an enemy. We will also assume that the tournament is not repeated: the rulers play the game once at the outset of their reigns. One might of course worry about dynastic considerations creating a repeated game, but foreign policy changed enough from ruler to ruler to make this a reasonable assumption.

In Fullerton and McAfee's model, n potential risk-neutral contestants (each with a cost c_i of exerting effort) simultaneously decide whether to enter the tournament and compete for the prize P. A potential contestant who decides to enter pays a fixed cost b and chooses to exert effort $z_i \geq 0$ to improve his innovation. The fixed cost may go for creating a navy or standing army, for establishing a fiscal bureaucracy to pay for military expenses, or for organizing a huge invasion force to fight an expensive land war in a distant country. We will interpret the cost c_i of exerting effort z_i as the political costs of raising taxes and bringing them under the control of the central government.[22]

The effort z gives the contestant a random innovation x, where x has cumulative distribution function $F^z(x)$ and the function F is absolutely continuous and has support $[0, a]$. (If a contestant enters and pays the fixed cost b but exerts no effort, then his innovation is $x = 0$.) The highest realized value of x wins the prize, and a potential contestant who does not enter the tournament

[21] Fullerton and McAfee 1999,

[22] As we will see below, centralizing tax revenues was essential for the gunpowder technology, but that was not necessarily the case for other military technologies.

avoids the fixed cost but has no chance for winning the prize. The innovations are independently distributed across contestants with the same distribution function F for all of them. If we ignore the fact that the effort z_i need not be an integer, then it would be as if each entrant were taking z_i independent draws from the underlying distribution F, and the parameter a could be interpreted as the limit to available knowledge—in other words, the limit to what effort can do.

If $J > 1$ potential contestants join the tournament, then the i-th entrant will turn out to have expected winnings of:

$$\frac{Pz_i}{\sum_1^J z_j} - c_i z_i - b$$

If only one contestant enters, he will exert no effort and will win $P - b$. These expected winnings can be interpreted as the expected gains from war if we apply a common functional form used in the economics of conflict. The effort would then simply be directed toward improving the effectiveness of the military, and the expected winnings would be value P of victory times the probability of winning, minus the costs of establishing a military and fiscal system and of exerting effort.[23]

As Fullerton and McAfee show, the resulting game has a subgame perfect equilibrium in which the potential contestants with the lowest costs c_i enter the tournament. (There may be other equilibria besides this low cost one, but they cannot involve firms whose costs are too high.) If the potential contestants are arranged according to their costs c_i from lowest (when $i = 1$) to highest (when $i = n$), then in this low cost equilibrium, only contestants 1 through m will enter, where m satisfies

$$P\left[1 - \frac{c_m(m-1)}{\sum_1^m c_i}\right]^2 - b \geq 0 \qquad (1)$$

$$P\left[1 - \frac{c_{m+1}m}{\sum_1^{m+1} c_i}\right]^2 - b < 0 \qquad (2)$$

If we let $(c_1 + c_2 + \ldots + c_m) = C$ and let Z denote the sum of the effort levels z_i exerted by each of the m entrants, then in this equilibrium,

[23]For an excellent overview of the relevant literature, see Garfinkel and Skaperdas 2007.

$$z_i = \frac{P(m-1)}{C}\left[1 - \frac{c_i(m-1)}{C}\right] \qquad (3)$$

and

$$Z = \frac{P(m-1)}{C} \qquad (4)$$

The resulting distribution of the winning innovation is $F^Z(x)$. Greater total effort Z will therefore mean more innovation in the sense that the expected value of the winning innovation x is higher. As Z approaches infinity, x will converge in probability to a, the limit of available knowledge, so that greater knowledge will also make for more innovation.

Several things are worth noting here. First, if only one contestant enters the tournament, then, since he exerts no effort, there will be no innovation. Second, if the potential entrants' costs c_i are all multiplied by $d > 1$, then (1) through (4) imply that the number of entrants remains the same but they exert less effort. As a result, there is less innovation when the political costs of effort are high. Third, a bigger prize P may draw more entrants into the tournament, but as long as their number remains the same, the bigger prize will increase effort by each entrant and therefore lead to more innovation. Fourth, it is possible to achieve arbitrary high levels of effort with just two entrants. So long as $c_2/(c_1 + c_2) < 2\, c_3/(c_1 + c_2 + c_3)$, one can choose P to generate the desired level of total effort $Z = P/(c_1 + c_2)$ and then simply adjust the entry costs b so that (1) and (2) are satisfied for $m = 2$. Fullerton and McAfee in fact show that under similar technical assumptions someone designing such a tournament can attain any level of effort Z (and hence any expected value of innovation) at lowest cost by limiting the tournament to two contestants.

Having more than one contestant in a tournament is thus essential if there is to be innovation; having more than two is unimportant. It is also clear what conditions will encourage more than one participant to enter. If $n = 1$, there can only be one competitor, but there may be only one entrant ($m = 1$) even if $n > 1$. That will happen if conditions (1) and (2) hold for $m = 1$, which will be the case if $P > b$ and $P < b(1 + c_2 / c_1)^2$.

Since adding potential contestants beyond the second one is unimportant, it suffices to consider the case $n = 2$, which is what we will do throughout the rest of the paper. Although that assumes away the problem of alliances, it is not unreasonable for the history we are trying to explain. The rulers we will consider typically had a chief enemy. For the Kings of France, for example, it was the Habsburgs in the sixteenth and seventeenth centuries, and the British in the eighteenth century. And while they had allies, the alliances were typically decided in advance and often confirmed by a marriage of the rulers or their relatives. It thus reasonable to treat them as exogenous, with the dominant ruler making the decisions for the alliance.[24]

[24] If alliances are possible and the tournament is interpreted as battling for victory in war, then why do potential enemies not form an alliance to share the prize without fighting? They would then avoid all the attendant costs of war. There are several reasons why. First, if the prize is glory, rulers actually have to fight to win it, or at least pay the tournament entry costs. Second, even token conflict may be impossible between allies, particularly if the alliances involve marriage, which would rule out a sham war. Third, if allies could credibly agree to share the prize without fighting, then there would presumably be no war and no expenditures on the military. Finally, it is possible to construct models where short term agreements such as alliances are possible, but war is still attractive. For the last two points, see Garfinkel and Skaperdas 2007.

Both rulers will then enter the tournament if $P \geq b(1 + c_2 / c_1)^2$. A valuable prize, low entry cost, and effort costs that are not too different will therefore encourage both rulers to join the tournament, and they will make a large total effort Z if P is large and the costs of effort are both low. The result will be innovation, and there will be all the more innovation if effort is not hemmed in by the limits to available knowledge—in other words, by a small value of a.

4 Testing the Model's Implications in Early Modern Europe

This simple tournament model fits early modern Europe well. The rulers of Europe were fighting for a valuable prize, be it glory, territory, commercial advantage, or an enhanced military reputation. The prize was valuable enough and the entry costs b low enough that there was always more than one ruler battling for the prize. We would therefore expect early modern rulers in Europe to exert effort, and the greatly increased per capita tax revenues (Table 3)—all at a time of little or no economic growth—confirm that implication of the model and suggest that the political costs C of exerting effort must have been relatively low.

That in turn implies that we should observe innovation and productivity growth in the military sector in early modern Europe. Descriptions of the military technology that dominated the warfare in western European at the time—the gunpowder technology—confirm this implication too, but there is quantitative evidence for it as well, for we can measure the rate at which the productivity of the technology was increasing.[25] The yardsticks used underestimate the productivity growth, because they fail to capture advances in tactics or provisioning that were an integral part of the gunpowder technology. They also have trouble with naval warfare, where western Europe's lead was perhaps greatest. The reason, beyond the scarcity of quantitative data for early navies, is simply that warships had variety of different goals, which varied over time. Firepower dominated the eighteenth century, but speed, range, and an ability to fight in inclement weather were also important, particularly in wars of economic attrition that were the focus of much early modern naval warfare.[26]

Yet despite all these difficulties, the evidence that military productivity was advancing in early modern Europe is clear. Suppose, for example, that we ignore the other goals navies pursued and take firepower (measure by the weight of the shot) as our sole yardstick of naval output, which we can divide by shipboard labor and capital to get an index of total factor productivity. In the English navy, this index was rising at a rate of 0.4 percent per year between 1650 and 1680, a period when firepower was gaining in importance.[27] Such a rapid growth was virtually unheard of in preindustrial economies, where total productivity was typically increasing at 0.1 percent per year or less (if it grew at all) in major sectors of the economy.[28]

[25] For an excellent account the technological change, see Parker 1996,

[26] Guilmartin 1974, 253-254; Guilmartin 1983; Glete 1993, 58-61.

[27] Capital here is computed from displacement, and labor from the size of the crew for the English navy as a whole. The data are taken from Glete 1993, 186, 195, 205, except for the factor shares (0.496 for capital and 0.503 for labor), which are derived from 1744 construction and crew labor costs in Boudriot and Berti 1994, 146-152. For the growing importance of firepower in this period, see Glete 1993; Guilmartin 2002.

[28] For examples, see Hoffman 1996; Clark 2007.

One might argue that measure is misleading because the English navy was simply specializing in firepower at the expense of speed or range—in other words, that it was moving along a frontier of output possibilities while productivity remained constant. But we can control for that possibility by considering earlier ships that had specialized in firepower. One of the earliest examples comes from the English fleet that fought the Spanish Armada in 1588. The English navy had already begun to emphasize bombardment as an alternative to the boarding that had been the customary goal in naval battles, and as a result the English flotilla in 1588 was heavily armed. If we compare these specialized vessels which confronted the Armada with their counterparts in 1680 and repeat the same calculation, we again find total factor productivity growth rates of 0.4 percent per year, but now it is sustained over a full century.[29]

Productivity in the English navy increased in other ways as well. Captains, for instance, learned how to became much more effective fighters, which drastically cut their fatality rate. If one holds constant the intensity and amount of fighting the captains were exposed to, their odds of dying in typical five year period fell from 16 percent in 1670-90 to one in a thousand in 1790-1810.[30]

Nor was productivity growth limited to naval warfare. On land, for instance, the effective firing rate per French infantryman jumped by a factor of 6 or more between 1600 and 1750, as bayonets made it possible to replace pike men and matchlocks were supplanted by flintlocks with ramrods and paper cartridges (Table 4). The higher firing rate translated into labor productivity growth of 1.5 percent per year, which rivals what developed countries experienced in the late twentieth century and far exceeds what one would expect for preindustrial economies.

Still another sign of rapid productivity growth was the falling price of weapons, which dropped faster than the cost of other manufactured goods from the late Middle Ages onwards (see Figure 1 for an example). The price of weapons—cannons, muskets, and pistols—also tumbled relative to the cost of the relevant factors of production. Using the dual, we can estimate productivity for weapons manufacturing in early modern France and England, and the median total factor productivity growth rate (over periods ranging from the late fourteenth century to the late eighteenth century) turns out to have been 0.6 percent—a rapid pace even at the outset of the Industrial Revolution.[31] The gunsmiths of late medieval and early modern Europe were getting better at making weapons, and as in modern industries the productivity growth was particularly rapid when new weapons were first introduced. When the first handguns appeared on the scene circa 1400 (they were little more than tiny, hand held cannons that could be fired from atop a city's walls), the metal founders in Frankfurt who cast them reduced the price drastically. They did so by cutting the amount of copper they used, so that the weight of the miniature cannons plummeted. That may seem obvious to us, but in an era when artillery regularly exploded, it marked real progress. The resulting total factor productivity for these handgun makers (3.0

[29] The Armada data come from Martin and Parker 1999, who discuss the shift to bombardment on pp. 33-36.

[30] Benjamin and Tifrea 2007, 981-984. As the authors argue, the lower death rates were not simply the result of Britain's naval dominance in the late eighteenth century, for they were already lower by 1710, before Britain's lead was overwhelming. The calculations are based on a hazard rate fractional logit regression and assume that the intensity and frequency of battle are held constant.

[31] For evidence and the economics of the argument, see Hoffman 2010. An alternative calculation yields an even higher median rate of total factor productivity growth, 1.1 percent.

percent per year between 1399 and 1431) was impressive by modern standards and astounding for the end of the Middle Ages.[32]

5 The Tournament and Why Japan Fell Behind

The tournament model explains why rulers in early modern Europe advanced the gunpowder technology of artillery, firearms, fortifications, and armed ships. But if it is to account for Europe's comparative advantage in violence, it should help us understand why early modern Japan, China, India, and the Ottoman Empire eventually fell behind. Presumably, either they did not have a tournament, or if they did, the conditions were different and did not promote improvements to the gunpowder technology.

The case of early modern Japan is easiest to understand, so let us begin there. After firearms were introduced in Japan in 1543, battling warlords and their opponents swiftly became experts in their manufacture and use, and they employed them with extraordinary skill in the virtually constant warfare that had wracked the fragmented country since the late fifteenth century. Just as in Europe, they innovated, at a furious pace, becoming, as we know, the first to use volley fire. And as in Europe, the ability to mobilize resources and to provision armies effectively proved critical with this technology. The military innovations ground to a screeching halt, however, once the country was unified in the late sixteenth and early seventeenth centuries.[33]

The pattern fits the tournament model almost perfectly. As long as the civil war continued, the warlords and the other combatants would be engaged in a tournament with a prize large enough to draw in more than one competitor. They would therefore have powerful reasons to improve their new military technology—the gunpowder technology—and while quantitative evidence is lacking, the military history suggests that they did. But once the country was unified, the tournament would be left with only one contestant, leaving the winner—the ruling Tokugawa Shogunate—with no incentive to advance the technology. Since there was no longer any reason to exert effort, the impetus to extract more resources for the central government would disappear too, and sure enough, its tax revenues declined as fraction of agricultural output.[34]

One might of course wonder why the victorious warlords who united the country did not turn to foreign conquests once they had vanquished their domestic enemies. But one them—Toyotomi Hideyoshi—actually did, in vain attempts to invade Korea (and via Korea, China) in 1592 and 1597. He failed, however, because he "lacked the resources" needed to carry out such

[32] Hoffman 2010,

[33] Parker 1996, 140-143; Chase 2003, 175-196; Berry 2005, and forthcoming work by Thomas Conlan. Philip Brown (personal communication) has pointed out to me that Japanese efforts focused on handguns. They made much less use of artillery and did not do as much to improve it or to develop the *trace italienne* fortifications that proliferated in Europe. The obstacle, in his view, was the poor transportation in Japan, which made it difficult to deploy artillery.

[34] Increasing revenues from the mint could provide an alternative explanation for why taxes were not raised, an explanation that might not have any direct connection to the tournament.

an operation—in particular, a large navy. Other Japanese leaders were "unenthusiastic" about the operation and "quickly" withdrew from Korea after Hideyoshi died. They seemed to realize that an invasion without adequate resources was unrealistic. They knew, in other words, that successful military competition against foreign powers entailed large entry costs, including the expense of building a powerful navy. Those entry fees—the *b* in the tournament model—ruled out the possibility of foreign war. The Japanese themselves were certainly better off, because the Tokugawa Shogunate brought an end to over a century of devastating conflict. Advances in military technology, however, stopped in Japan, despite an enduring cultural attachment to martial values.[35]

6 More Complex Cases: Early Modern China, India, and the Ottoman Empire

Can the tournament model also explain why early modern China failed to keep up, even though it was the birthplace of gunpowder weapons? And can the tournament do the same for early modern India and the Ottoman Empire?

It can, but to see why we have consider other possible ways early modern rulers could protect their realms. War was a threat everywhere, but there were ways to defend a country without using gunpowder weapons or straining to improve the associated military technology. Diplomacy could weaken enemies by pitting one against another. Selective access to trade could pacify them. The Chinese employed both strategies against their major enemy—central Asian nomads on horseback—and the Spanish proposed doing the same against the nomadic Comanches on the fringes of their American Empire.[36]

Much of Asia and the Middle East in fact faced attacks by nomads. Where they were a menace, diplomacy and strategic trade might be all the more attractive because the gunpowder technology was (for a long time at least) of relatively little use against them. Nomads, after all, had no cities to besiege, and they were too mobile to be targets for artillery. Sending the infantry chasing after them would demand too many provisions, since the nomads could simply ride off into the steppe and live off the land. Muskets gave no advantage, because they could not easily be fired from horseback, and while pistols could, their range was limited. When fighting the nomads, the best option was usually dispatching cavalry of mounted archers, essentially the same weapons the nomads themselves utilized. But that venerable technology had been around since perhaps 800 BC, leaving little room for further innovation via learning by doing, even if there were a tournament, because the limits of available knowledge would have been reached. In short, against nomads who galloped off the steppe, it made little sense to devote effort to improving the gunpowder technology. The rewards, or prize, would be minimal. It would be better to deploy

[35] For this and the preceding paragraph, see Smith 1958; Reischauer, Fairbank et al. 1960, 1:614-615; Berry 1982, 207-217 (the quotations are from 213); Berry 1986, 207-217; Brown 1993; Guilmartin 2002, 182-190; Chase 2003, 175-196; Berry 2005. According to Philip Brown (personal communication), the central government's stagnating tax revenues in the early Tokugawa Shogunate may have reflected how vulnerable the immediate successors to the first shogun (Tokugawa Iyeasu) were after his death 1616. Stagnating tax revenues did not mean, however, that the central government lost control of the warlords—far from it.

[36] For this and the following paragraph see Barfield 1989; Rossabi 1998; Chase 2003; Gommans 2003; Perdue 2005; Hämäläinen 2008, 131-133.

the ancient technology of archers and swordsmen on horseback, even if it could not be improved much. Or better yet, use diplomacy and strategic access to trade and avoid the cost of war.

There were of course powers in Asia and the Middle East that were vulnerable to the gunpowder weapons. But in potential war against them rulers might not have been willing to enter any tournament because the prize was too small or the entry costs too high. And even if other countries joined the fray and vied against one another, the political costs required by the gunpowder technology (particularly that of raising and centralizing taxation) might have loomed too large for rulers to devote much effort to improving the gunpowder technology. They might have used gunpowder weapons but they would not advance the technology's cutting edge.

With these conditions in mind, let us turn first to the case of China and see whether it fits the model of the tournament. Since China faced attacks by nomads, the gunpowder technology was (for a long time at least) of relatively little use. There would therefore be little reward for trying improve it. There would be little reason either to centralize provisioning and tax collection, since it might simply be more effective to have soldiers settle near the frontier regions where the nomads were most likely to attack. They could then make some of their own equipment and grow some of their own food on land they were allotted, and thus spare some of the cost of shipping resources. Military decentralization of this sort was in fact common not just in China's history but in other parts of the world where attacks by nomads posed a threat, and it too discouraged use of the gunpowder technology and efforts to improve it. The reason was that with military forces dispersed in frontier regions there was less reason to incur the political costs (and economic costs in an era of expensive transportation) of centralizing tax revenues. The gunpowder technology depended, however, on bringing revenue collection under central government control, at least before the nineteenth century. Economies of scale in provisioning for armies and navies made centralization essential, and so did the risk of desertion in an era before nationalism motivated armies, for if troops were scattered in small independent units, they could easily slip away. For navies, centralizing revenues and expenditures was advantageous because the supply of suitable deep water ports for warships was limited and because there were economies of scale in the operation of dry docks needed for maintenance. Similar arguments apply to fortifications that could stand up to an artillery barrage.

China's leaders had other possible defenses against the nomads as well, none of which depended heavily on the gunpowder technology. They built fortifications such as the Great Wall to keep the nomads out, or they bestowed honors and rights to trade upon the nomads in return for being peaceful and used diplomacy to keep them from uniting into a major military menace.[37]

That does not mean that China shunned the gunpowder technology altogether. The technology in fact gained in appeal in the early seventeenth century, when an arms race began to develop in East Asia. As the Ming dynasty, beset by rebellions and under attack by the Manchus, fell into decline, its troops fought and defended besieged cities with muskets and artillery. Their opponents replied in kind. But when Ming dynasty fell and China was unified under the

[37] The previous two paragraphs are based on Fairbank 1974; Franke 1974; Hucker 1974; Loewe 1974; Mote 1974; Peterson 1974; Barfield 1989; Chase 2003; Perdue 2005. By the Ming dynasty, cannons and handguns were being used in the fortifications that protected against the nomads Lorge 2005,

Manchus, the arms race was cut short before it could radically change military technology. The successor Qing dynasty then had less reason to rely on the gunpowder technology, because it was still not terribly effective against their remaining major enemy—nomads—for the simple reason that it strained supply lines to the breaking point. That is why the Qing continued to resort to diplomacy and the strategic use of honors and trade, at least until the middle of the eighteenth century, when its supply lines finally grew strong enough to allow it to wipe out the last major nomadic threat, the Zunghars.[38] In short, the military dangers facing China often made the gunpowder technology unappealing, and when there finally was a tournament to improve it, the contest came to too quick an end.

Another factor also worked against military innovation in China, no matter what the technology was: the size and durable unity of the empire. For nearly half of the two millennia between 221 BC and 1911, the Chinese Empire was intact; western Europe, by contrast, spent much more time fragmented into warring states. Indeed, after the fall of the Roman Empire, western Europe lived through a millennium and a half of nearly uninterrupted disunity. More often than not China was thus in a situation like Japan after it was unified under the Tokugawa Shogunate: even if a Chinese emperor had wanted to compete in a military tournament, he would be the lone contestant and have no reason to exert any effort. He could conceivably have built an effective navy or fought distant land wars but that would have meant paying prohibitive entry costs. The only time when there would be more than one potential contestant in China would be when the empire happened to be under attack or was fragmented into hostile powers. That is in fact when we would expect to see military advances in China, though not necessarily with the gunpowder technology.

There is one final condition that may have kept the Chinese from pushing the gunpowder technology. When this technology finally became appealing in the seventeenth century, it may simply have been more advantageous to acquire it from the Europeans, by asking the Portuguese or the Jesuits to provide designs and expertise.[39] The European rulers, after all, had already been through a tournament. They had already spent heavily on improving the gunpowder technology and become specialists in its use. A Chinese emperor might find it much cheaper to buy the European innovations by hiring European experts, rather than trying to duplicate it or improve it on his own. The relative prices of weapons in China and the direction of trade in military expertise certainly point in that direction.[40]

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[38] Here I am relying on Needham 1954, 5, part 7: 398-407; Atwell 1988; Perdue 2005, and ongoing research by Bozhong Li and Guanglin Liu. One additional factor worked against the development of the gunpowder technology in China: in contrast to Europe, the private production and ownership of guns was limited in China: Chase 2003, 151-154; Perdue 2005, 119.

[39] Spence 1969, 15, 29; Chase 2003, 167-171 and Li Bozhong, personal communication. The issue was not the ability to cast metal, for Chinese craftsmen were likely as good or better than Europeans at doing that. Rather, it was the design and testing of the cannons.

[40] If the fragmentary data from the early seventeenth century are believable, the price of muskets in China (measured relative to food) was 3 to 9 times higher in China than it was in England or France. Large numbers of military advisers and experts in the gunpowder technology were also hired in East and South Asia, as early as the sixteenth century. For the evidence, see Hoffman 2010. Cheaper capital may have also contributed to Europe's comparative advantage in the gunpowder technology (particularly with capital intensive naval warfare), but the tournament argument, which relies on learning by doing and the efforts spent on improving the technology, would hold even if the relative price of capital in China and Europe were the same.

Quantitative evidence bears out these claims about China. The Chinese did invent a large number of weapons—more than just gunpowder and firearms—and not surprisingly the discoveries tended to be made when emperors were at war.[41] But over the years 1500-1799, China was less likely than major European powers to be fighting foreign enemies against whom gunpowder weapons might prove useful. Most of the hostilities it engaged in were civil wars or battles against nomads, which gave less of an impetus for innovation.[42] If these two sorts of strife are set aside, the contrast with major European powers is striking (Table 5). So at the very time when gunpowder technology was advancing, China's rulers had less reason to cultivate the new weapons, and the Chinese military had much less experience with them. Greater experience could of course translate into learning how to improve the technology, as with British naval captains.

The Chinese emperors also did less to raise and centralize taxation, as would be expected if they were not embroiled in a tournament involving the gunpowder technology. The evidence for China is admittedly scanty, but it suggests that the government's per capita tax receipts (in grams of silver) were in fact much lower than in European powers such as England or France (Table 6). The difference is particularly pronounced if we consider the fraction of tax receipts that were under the central government's control.[43] The higher tax burden in Europe is a sign of the enormous effort the tournament elicited. Political conditions in China were different, for fighting China's enemies had traditionally not hinged on high centralized taxes, and taking steps to raise or centralize them could easily provoke rebellion. That was true in particular at the end of Ming dynasty, and it limited the dynasty's to acquire gunpowder weapons.[44]

A similar argument fits the Ottoman Empire, which had to confront both nomads and enemies who employed the gunpowder technology.[45] At the same time, their navy had to focus on the Mediterranean, where galleys long rule supreme, but that kept them from emphasizing the more heavily armed sailing ships that came to dominate ocean warfare. The Ottomans could therefore not devote all their resources to the gunpowder technology, as the Europeans could. That would raise the cost of any effort they might exert to improve the gunpowder technology if they joined a tournament against the Europeans. So too would the growing difficulty the Ottomans had in raising and centralizing taxation, particularly in eighteenth century, when the

[41] Margaret Chen, a graduate student in economics at UC Davis, has gathered data on Chinese military inventions over the past three millennia. Other things being equal, the military inventions were more common under dynasties that spent more than half their time at war.

[42] This is not to say that use of the gunpowder technology was pointless during rebellions and battles against the nomads. It was no doubt useful, particularly when troops rebelled at the end of the Ming dynasty. But battles against rebels and nomads did not usually threaten the emperors with better technology.

[43] The Chinese figures, it is worth stressing, err on the side of overestimating both per-capita tax receipts and the fraction under the central government's control. Measuring taxes in gold rather than silver might erase the difference between China and England in 1578, but it would still leave China well behind France, and it would do nothing to the gap in 1776.

[44] Huang 1970; Huang 1998.

[45] Russia (which space keeps me from analyzing here) faced a similar dilemma, but it could exert effort at lower political cost than the Ottoman Empire and it therefore became a major military force in the eighteenth century, although most of its expertise with gunpowder weapons was imported: Esper 1969; Poe 1996; Hellie 2002; Kotilaine 2002; Paul 2004,

central government's tax receipts failed to keep up with collections in western Europe. The high costs of raising and centralizing taxation (probably the greatest obstacle the Ottomans faced) would greatly diminish the effort they would devote to making the gunpowder technology better, even if they were fighting the Europeans.[46] If the Ottomans with effort cost c_2 entered a two-player tournament against a European power with much lower effort cost c_1 , then the ratio of Ottoman effort to European effort would (from Equation 3) be c_1 / c_2 . In short, the Ottomans would wage war; deploy musketeers, artillery, and armed naval ships when appropriate; and manufacture cannons too. But they would do relatively little to advance the gunpowder technology on their own. Instead, they would import cutting edge weapons and expertise from the Europeans, especially after 1700, when the political costs they faced were highest. And that is precisely what happened.[47]

The most telling comparison for the early modern period, however, is between Europe and India, which should have been fertile ground for advances in gunpowder technology, if the traditional argument about competition were correct. India was ravaged by virtually constant warfare and had highly developed markets for military goods and services.[48] The claims about competition would predict that Indians would therefore push the gunpowder technology further, yet while they readily adopted new weapons and tactics, they did not break new ground in their use. The innovations, by and large, came from the West with renegade experts, officers, and imports of weapons.[49] That runs counter to what the claims about competition would lead one to expect.

Part of the reason was that India, like the Ottoman Empire, had one foot in the zone where nomads fought. Armies were predominantly (though not exclusively) cavalry, particularly under the Mughal Empire, and for a long time the gunpowder technology was of little use. But when the Mughal Empire fell apart in the eighteenth century, the gunpowder technology became advantageous. Yet even then the Indians failed to innovate. Their highly developed military markets meant that they quickly embraced the latest that the gunpowder technology had to offer, but they did not push it further on their own.[50]

The tournament model can explain why. There was in fact a military tournament in India, with multiple contestants entering the fray from among the leaders and states that arose as the Mughal Empire disintegrated. The conditions of the tournament, however, differed greatly from those in Europe and worked against improvements in the gunpowder technology. One difference was that strife often broke out within powerful Indian families over succession to a throne or rights to rule.[51] Conflict of this sort, which had grown rare in Europe after the late Middle Ages, reduced the value of the prize P in the Indian tournament, by raising the odds that a prince or

[46] The argument about the Ottomans and nomads is taken from McNeill 1964; Chase 2003; Headrick 2010, and the evidence about Ottoman taxes from Pamuk and Karaman 2010.

[47] Parry 1970; Agoston 2005, 10-12, 193-194.

[48] Kolff 1990; Gommans and Kolff 2001; Gommans 2003.

[49] Even defenders of Indian military prowess admit that the advances with the gun powder technology by and large came from the West. See Subrahmanyam 1987; Barua 1994; Alavi 1995, 24-25; Cooper 2003, 31-32, 42-44, 289-294.

[50] Kolff 1990; Gommans and Kolff 2001; Gommans 2003.

[51] Gommans 2003.

other ruler would be unable to enjoy fruits of victory. The prize was large enough to get Indian rulers to join the tournament, but not big enough to get them to exert huge amounts of effort $Z = P/C$ to upgrade weapons, tactics, and administration.

The effort the prize elicited was reduced even more by the high political and economic costs C of centralizing taxation and army funding. The problem was that it was easy for Indian military leaders and other members of the elite to defect and join the enemy. Behavior of that sort was less common in Europe, particularly after the early seventeenth century. Indian rulers might therefore have hesitated before raising or centralizing taxes out of fear that elites would jump ship.[52] In addition, grain markets in eighteenth and early nineteenth-century India were more fragmented than in Europe, which would make centralizing provisioning and tax collection for the gunpowder technology all the more difficult.[53] Together, the higher political and economic costs C and the lower value of the prize P would mean less effort $Z = P/C$ overall and less innovation. The Indian rulers would therefore import the latest gunpowder technology, but they would do little to improve it.

If we consider the most powerful successor states to the Mughal Empire, most of them did fail to develop to develop centralized tax and supply systems. That is a telltale sign that conditions in the Indian tournament were different, because advancing the gunpowder technology depended on centralizing the fisc and provisioning. In this situation, the British East India Company had a considerable advantage in India, even though it was only a private enterprise, because it could easily use its own financial system, which was already in place, to centralize the funding of its military operations. Historical accidents also worked in the Company's favor. It had gained control over parts of the fertile Ganges plain in northwestern India, where transportation costs were relatively low and market fragmentation less of a problem. It thus faced fewer obstacles to centralizing taxation, and it won the support of elites for higher taxes by offering them a land market in return. The result was that the Company could raise revenue and mobilize funds at minimal political cost, and it proceeded to conquer much of the subcontinent, simply by hiring away the best officers and their troops.[54]

6 Nineteenth Century Europe

After 1815, the incessant warfare that had bedeviled Europe virtually disappeared. Diplomats at the Congress of Vienna had fashioned a coalition that discouraged wars within Europe (the rest of the world—including colonies—was another matter), and the coalition endured until late in the century. Some battles were fought, but by the standards of the past, they were short and (by the standards of the past) relatively bloodless, allowing the continent to bask in peace until the onset of World War I (Table 1).[55]

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[52] Gommans and Kolff 2001; Gommans 2003,

[53] Studer 2008,

[54] Alavi 1995; Gommans and Kolff 2001; Cooper 2003; Gommans 2003. The important argument about historical events working in the East India Company's favor is due to Roy 2010, who notes that the Company also benefitted when several other major competitors for military powers temporarily dropped out of the contest. On that point, see also Chaudhuri 1982, 393-395; Chaudhuri 1983, 87-100

[55] Schroeder 1994, vii, 574-575, 581, 799-803. In Table 1, most of the wars in the years 1800-1850 were fought before 1815. If they are removed, the number of years at war drops sharply.

With warfare subsiding, did the tournament fade away too? It might seem so. Nonetheless, military technology continued to evolve, as rifled handguns and artillery replaced smooth bore muskets and cannons, and steam powered gunboats and armored battleships took the place of sailing ships.

The tournament model can tell us why. In Europe after 1800, losing a war began to carry the risk, even in the major states, that a ruler would be toppled from his throne or from power (Table 2). There was now a downside to war, but from the perspective of the tournament, the penalty for losing simply meant a larger fixed cost b and a bigger prize P.[56] The nineteenth century witnessed political and administrative reforms as well, which affected the cost of effort. During the Napoleonic Wars, states pushed centralization of their fiscal systems further than ever before, and later in the century representative assemblies gained a voice in fiscal decisions. Cumulatively, the reforms made it easier to raise and centralize taxes and hence diminished the political cost of effort.[57] Patriotism and conscription had the same effect.

The higher fixed cost b would raise the entry threshold $b(1 + c_2 / c_1)^2$ at which both rulers join the tournament. The prize P would increase too, and if it still exceeded the threshold, then more than one ruler would still join the tournament. The effort P/C that they would expend would rise above what it would have been earlier, for P would now be higher, and the cost C, lower. The greater effort would then translate into even more expected innovation, because spillovers from the Industrial Revolution would have expanded the limit a of available knowledge.

That was the outcome in nineteenth century Europe, for military rivalries persisted despite less actual fighting. If we modify the model, we can assume that these contending major powers faced a lower entree fee b because part of b was a sunk cost, such as establishing a tax system. We can assume that other countries—in particular, those from outside Europe—would have no such advantage, for they would have to match the sunk costs if they tried to enter the tournament. That would be a major obstacle to catching up with the major European military powers. Such outsiders could certainly buy the Europeans' old technology but they would never match the major European powers on the battle field. Alternatively, we could reformulate the model as a multiperiod game, with European rulers able to maintain short term peace agreements provided that their militaries were strong enough to dissuade potential future attackers. [58] The tournament would continue and so would advances in military technology, but there would be little or no warfare, as in Europe after 1815.

[56] If rulers faced a penalty $d > 0$ for losing wars they had entered, then the payoffs for the defeated entrant will then change from $-b$ to $-b - d$, while the victor's payoff will remain $P - b = P + d - b - d$. But that is identical to what the payoffs would be if the rulers were playing the original game with a higher entry cost $b + d$ and a larger prize $P + d$.

[57] Dincecco 2009.

[58] For such a model, see Garfinkel and Skaperdas 2007; McBride and Skaperdas 2007, Such an armed peace is more likely when war is more destructive and when rulers risk losing office, as was the case after the wars for the French Revolution.

There was one other critical difference in the nineteenth century. In the early modern world, technology advanced primarily via learning by doing and occasional random discoveries. The military sector was no exception. Although some research was done, most technological progress in weapons and tactics was eked out by learning on the job—in other words by fighting wars and then using what worked. But in the eighteenth century, this arduous process began to change, as the Enlightenment encouraged the collection of useful knowledge. It became possible to improve military technology without actually fighting, simply by doing research or applying newly discovered engineering techniques. The task became even easier in the nineteenth century, with the growth of engineering know how during the Industrial Revolution.[59]

When, for instance, the French navy added steam warships in the early 1840s, British leaders grew fearful of a possible invasion and quickly jumped into a naval shipbuilding race with France. In a short time, the arms race and the research it triggered led both the British and French navies to adopt the latest in steam technology—the screw propeller—which was less vulnerable to gunfire than the initial method of steam propulsion, paddle wheels. Yet Britain and France did not go to war to begin the process. They relied on research, including an 1845 tug of war in Britain between a steamship with a screw propeller and another one with paddle wheels.[60]

Thus, despite less time spent at war, the major European military powers were still competing in a tournament in the nineteenth century. Their effort were now devoted more to research and to building up the potential of their armed forces than to actual fighting, at least within Europe itself. Imperial wars, however, were not ruled out by nineteenth century diplomacy, and thanks to the military innovations that the ongoing tournament produced (rifles and steam gunboats are prime examples) it was now much easier to acquire colonies.[61]

8 Conclusion

The tournament model yields a deeper understanding of why Europeans pushed the gunpowder technology so far and why therefore they were the ones to conquer the world. The rulers of western Europe's major powers were competing in a tournament, under conditions that drove them to improve the artillery, firearms, fortifications, and armed ships that they deployed in their wars. Since the gunpowder technology required it, they raised taxes and strove to centralize provisioning and the fiscal system. They overspent on the military and provided more defense than their subjects likely desired. But they had little reason not to. Victory in the tournament won them glory, enhanced reputations, and resources and territory snatched away from smaller neighbors. Before the French Revolution, losses never cost them their throne, at

[59] For the Enlightenment and the growth of useful knowledge in general, see Mokyr 2002. Military examples would include experiments improved the quality of British gunpowder during after the American War of Independence, and late eighteenth-century trials of copper sheathing that protected wooden hulls against shipworms and increased ships' speed British navy. The effect was huge: warships were up to 20 percent faster, and since they spent less time being careened, the number of vessels available increased one third. For details, see Rodger 2004, 344-345, 378 . Improvements to French artillery after the Seven Years War provide yet another example.

[60] Lavery 1983-1984, 1: 155; Glete 1993, 443-446, 450, 455; Corvisier and al 1997, 2: 490-497. Working screw propellers, which emerged in the 1830s, were not invented by the navies. The passage to steam powered warships with propellers was not immediate, and the results of the Crimean War (1853-1856), in which both France and England were allied, did play a role in winning over decision makers.

[61] Headrick 1981.

least for the major powers and as long as they faced no civil war. Furthermore, the rulers did not bear the full costs of warfare, and neither did elites with political voice, who in any case often aspired to military careers.[62]

The economic and political costs of raising and centralizing fiscal systems were lower in Europe than they were in India or the Ottoman Empire, and the tournament prize was not diminished by frequent strife over succession. And in Europe, the market for weapons and military skills helped prevent one country from getting too far ahead, although there was an important element of historical contingency involved. Had one power crushed the others—the Habsburgs in the sixteenth century, or Napoleon at the height of his power—then the tournament in Europe would have halted, as it did in early modern Japan. But that never happened in Europe. It never enjoyed the political unity that would have cut the incentives for military innovation, as in China, or in Japan under the Tokugawa Shogunate.

Other factors also worked in Europe's favor, in particular the fact that western Europe faced no threat of attack by nomads. The rest of Eurasia did have to confront nomads, and against them, the gunpowder technology—and the centralized provisioning and tax collection that went with it—were of little use. The gunpowder technology therefore lost part of its appeal for the Ottomans, and it was even less attractive for the Chinese. But even here the tournament gives us insight. When the technology finally did become advantageous, as in eighteenth-century India and in seventeenth-century China too, it was cheaper to buy it from the Europeans. Rulers in Asia and the Middle East could simply purchase the results from the previous round of the tournament in Europe from European mercenaries and arms merchants. They would get technology that, while not cutting edge, was cheaper (both economically and politically) and sufficient for wars against non-European opponents.

This expertise in turn allowed the Europeans to wage war at a distance. Not that they were posting huge infantry armies abroad. But they could dispatch ships armed with cannons to prey upon trade in places as far away as Southeast Asia, and for protection, ship maintenance, and essential supplies of water and fresh food, the ships could rely upon European style fortresses, which, when built in Asia or the Americas, could be defended with a relatively small force. The fortresses thus complemented the naval forces and allowed the Europeans to hold critical trading posts and to protect what land they conquered without sending large numbers of officers and men abroad—an expensive undertaking given the high mortality rates during long voyages. And the defense worked both against attacks by native powers and by other Europeans, who were always a threat.

To make this whole argument persuasive, there are still questions that need to be answered. To begin with, why did the tournament not come to a stop in Europe—as it did in Japan—with one ruler annihilating his opponents? That question becomes even more puzzling if we allow the rulers to play the tournament repeatedly. Suppose, for instance, that we extend the model to two periods and give the winner in the first round the possibility of killing off the loser at low cost and then facing no opponent in round two. Winners would then always wipe out losers in the first round and then exert no effort in the second. Such a pattern of effort suddenly halting would

[62] Hale 1985, 91-140; Cornette 1993, 294; Hanlon 1998, 241-267; Drevillon 2005; Bell 2007, 5-48.

not jibe with the record of sustained increase in taxes and in military productivity in early modern Europe, and it would be impossible to reconcile with examples of early modern monarchs who actually spared enemy kings when they took them captive. Annihilating an opponent was simply not an appealing strategy in early modern Europe, perhaps because the political costs of taking over a major opponent's kingdom were simply too large.[63]

A second issue is explaining what determined the choice of a particular military technology. Some technologies were obviously more effective against particular enemies (archers on horseback against nomads, for example), but in some instances, the choice would presumably be affected by other factors, such as the relative price of capital and military labor. Navies, for instance, were capital intensive, and if capital was dear, then a coastline could be defended with land forces, although ocean shipping would then be vulnerable. China's rulers seem to have made such a choice in the early modern period, and one of the reasons may have been that relative cost of capital was high.[64] The choice of technology would in turn affect the rate of technical change, at least in the early modern period, when possible gains from learning by doing with an old technology would be hemmed in by the limits of available knowledge. For gunpowder that constraint was still far from binding.

Finally, why did the rulers of early modern Europe face incentives that give them every reason to join the tournament and little reason to hold back? Napoleon and the wars of French Revolution did finally overturn the rules of the game: henceforth losing at war could cost the ruler of a major power his throne (Table 2). Where did these ancient incentives originate and why did they finally change? Far back into the Middle Ages, Europe had overspent on warfare, with consequences for the economy that were at best mixed and at times disastrous, particularly when battles were fought on land. With a century of peace after 1815, was it any surprise that the continent swiftly followed the British example and industrialized?

[63] Statistical evidence I have assembled suggests that the same was true for major powers throughout Eurasia.
[64] See Allen 2009; Wong and Rosenthal 2011.

Table 1
Frequency of War in Europe

Period	Average Percentage of Time Principal European Powers Were at War
1550-1600	71
1600-1650	66
1650-1700	54
1700-1750	43
1750-1800	29
1800-1850	36
1850-1900	23

Note: The principal European powers are defined as France, Austria, Great Britain, Russia, Prussia, Spain, Netherlands, Sweden, Denmark, Turkey, and Poland.

Source: Wright 1942, 1: Tables 29, 45, 46; Levy 1983, leads to similar results.

Table 2
Probability That a Major European Sovereign Was Deposed After Losing War

	Fraction of Losing Sovereigns Deposed			
	Excluding Civil Wars		Including Civil Wars	
Period:	1498-1789	1790-1920	1498-1789	1790-1920
Country				
Austrian Dominions	0.00	0.06	0.00	0.12
France	0.00	0.05	0.02	0.09
Great Britain	0.00	0.00	0.03	0.00
Hohenzollern Dominions	0.00	0.07	0.00	0.06
Netherlands	0.00	0.20	0.10	0.33
Spain	0.00	0.13	0.00	0.16
Sweden	0.00	0.13	0.00	0.13

Note: Wars are taken from the list in Clodfelter and are dated by when they end. Wars that involved no great powers are excluded, with Levy being the source of the list of great powers and the dates of their being great powers. Being deposed includes being exiled, imprisoned, maimed, executed, or forced to commit suicide. It does not include dying in battle, which would not greatly change the table. Sovereigns lost a war when they ceded territory, or their armies fled, or Clodfelter or Langer said their opponents were clearly victorious. Sovereigns included all monarchs, whether absolute or constitutional. For republics, the sovereign was the parliament or legislative assemblies; if the legislative assemblies shared sovereignty with a president or other executive, then the sovereign was the executive and the legislative assemblies together. During Charles V's reign as Holy Roman Emperor, his holdings as King of Spain are included in the Austrian dominions.

Source: Langer 1968; Darby and Fullard 1970; Levy 1983; Clodfelter 2002.

Table 3
Central Government's Per-Capita Tax Revenue, 1540s-1780s

	Per-Capita Taxes (Grams of Silver)	
Country	England/Great Britain	France
1540s	27.52	9.13
1780s	171.69	68.86
Increase	6.24	7.54

Note: Data are missing for some years in each decade. Silver conversions are based on mint prices.

Source: For the French revenue and population figures, see Hoffman and Norberg 1994, 238-239 and the sources listed there. For England (in the 1540s) and Great Britain (in the 1780s), the revenue figures come from data collected by P. K. O'Brien and P. A. Hunt and posted at the European State Finance Data Base that Richard Bonney has assembled (http://www.le.ac.uk/hi/bon/ESFDB/dir.html); and from evidence gathered by Mark Dincecco and made available at the Global Price and Income Group web site at http://gpih.ucdavis.edu/ and in Dincecco 2009. The population figures are taken from Wrigley, Schofield et al. 1989, Table 7.8 for the 1540s and from Dincecco's data for the 1780s. The Global Price and Income web site is also the source of the silver conversions.

Table 4
Military Labor Productivity in the French Army:
Rate of Successful Fire per Infantryman, 1600-1750

Approximate Date	Rate of Successful Fire per Handgun (shots/minute)	Handguns per Infantryman	Rate of Successful Fire per Infantryman (shots/minute)	Assumptions
1600 (1620 for handguns per infantryman)	0.50	0.40	0.20	1 shot per minute with matchlock; 0.50 misfire rate
1700	0.67	1.00	0.67	1 shot per minute with flintlock, 0.33 misfire rate; bayonets have led to replacement of pike men.
1750	2.00	1.00	2.00	3 shots per minute with flintlock, ramrod, and paper cartridge; 0.33 misfire rate.

Notes: The calculation considers only pike men and infantrymen with firearms; it ignores unarmed solders, such as drummers. The implied rate of labor productivity growth over the 150 year period from 1600 to 1750 is 1.5 percent per year.

Source: Lynn 1997, 454-472

Table 5
Frequency of Foreign War in China and Europe, 1500-1799

	Fraction of Years at War Against Foreign Enemies	
Country	With Wars Against Nomads	Without Wars Against Nomads
China	0.56	0.03
France	0.52	0.52
England/Great Britain	0.53	0.53
Spain	0.81	0.81
Austrian dominions	0.24	0.24

Note: Austrian dominions and Spain as in Table 2. The data for this table were collected by Margaret Chen, except for those for China, which were kindly furnished by James Kung. Chen also collected figures for China from the Chinese sources above, and her numbers were similar. Excluding wars against nomads does not change the figures for the western European countries because they did not fight wars against nomads.

Source: Micheal Clodfelter, *Warfare and Armed Conflicts: A Statistical Reference to Casualty and Other Figures,1500-2000 (*McFarland &Company, 2002); Quincy Wright, *A Study of War*, 2 vols. (University of Chicago Press, 1942); Zhongguo Junshi Tongshi (Military History of China), vols. 15-17 (Junshi Kexue Press, 1998); Bai Shouyi, editor,vol.8-10, Zhongguo Tong Shi, vols. 8-10 (Shanghai People's Press, 1999); Peter N. Stearns, The Encyclopedia of World History, page 376-381; and James Kung (personal communication of the figures for China).

Table 6
Annual Per-Capita Taxation in China, England, and France, 1578 and 1776
(in grams of silver)

		1578	1776
China	Total	6.09	8.08
China	Portion under central government control	3.56	7.03
England	Portion under central government control	10.47	180.06
France	Portion under central government control	16.65	61.11

Note: The figures for England and France are decennial averages. For China, they are upper bound estimates that involve the following assumptions: the population is 175 million in 1578 and 259 million in 1776; the grain levy in 1578 is converted to silver at 1 shi equals 0.6 taels of silver; the service levy in 1578 is worth 10 million taels per year; the portion of taxes under central government control in 1578 includes taxes sent to Beijing or Nanjing, plus 25 percent of the service levy; 87 percent of the taxes are under central government control in 1776.

Source: For England and France, the sources are as in Table 3, except that Wrigley and Schofield's Table A3.1 is used for population. For China the sources are Huang 1998; Myers and Wang 2002; Liu 2009; and the Global Price and Income History Group (gpih.ucdavis.edu) for units, silver equivalents, and prices of grain in China.

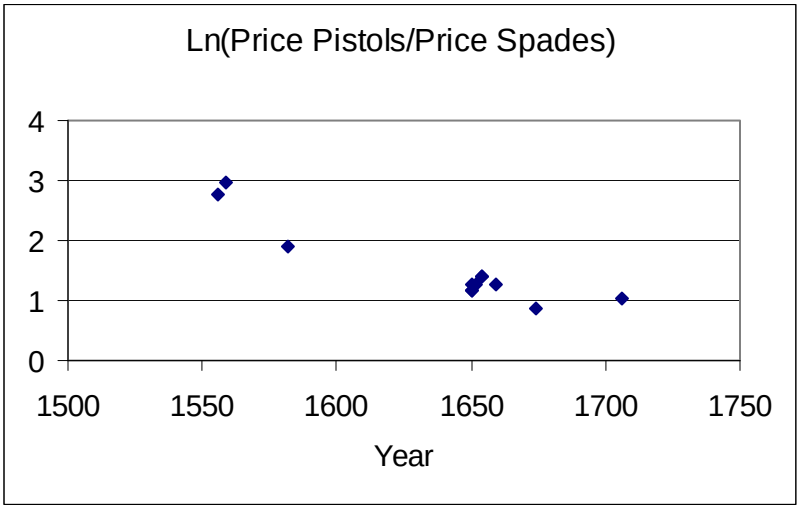

Figure 1
The Logarithm of the Price of Pistols over the Price of Spades in England

Source: Hoffman 2006.

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